



Carbon Dioxide Information Analysis Center  
World Data Center for Atmospheric Trace Gases  
Oak Ridge National Laboratory

# Communications

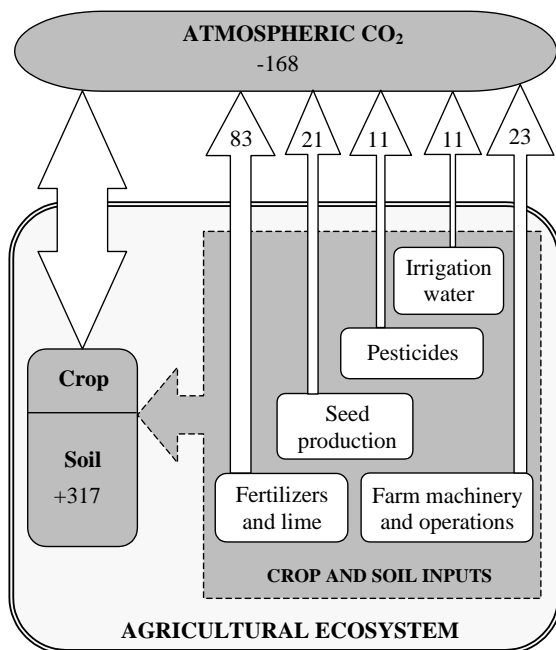
## Carbon Emitted, Carbon Saved

by Gregg Marland, Tristram O. West, John C. Fenderson

The concentration of greenhouse gases in the atmosphere continues to grow, and there is increasing interest in trying to minimize emissions. Countries and corporations are conducting inventories of their emissions and investigating how changes in some practices might lead to reduced emissions. If ratified, the Kyoto Protocol would permit countries to trade emissions permits. In conducting the inventories and related analyses, analysts and policymakers need to clearly understand system boundaries and their significance.

The inventories' system boundaries are based on national boundaries in a purely physical sense. Thus inventories of national CO<sub>2</sub> emissions, reported on the CDIAC Web site in terms of tons of carbon, cite emissions that physically occur from within a given country. If the United States, for example, imports electricity that was generated from burning coal in Canada, the CO<sub>2</sub> emissions will be recorded in the inventory for Canada, where the emissions occur.

*Continued on p. 12*



Carbon flows and stock changes during the first year after conversion from conventional tillage to no-till agriculture for the average U.S. crop. Numbers on arrows show flows of carbon from the use of fossil fuels for production, processing, transport, and application of agricultural inputs. Numbers in boxes show the net change in carbon stocks. All values are in kg C/ha/yr. Savings in net carbon emissions for conversion to no-till agriculture would be calculated by comparing these numbers with comparable numbers for continuation of conventional tillage. Based on data in West, T.O. and G. Marland, 2001. A synthesis of carbon sequestration, carbon emissions, and net carbon flux in agriculture comparing tillage practices in the United States. *Agriculture, Ecosystems and Environment* (in press).

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Co-editors: Sonja Jones  
Karen Gibson

### What's Inside...

Director's Desk	2
AmeriFlux Data	3
Trends Online	5
Carbon Sequestration	8
Focus Areas	9
energy.gov	11
New and Updated	14
Reference Links	19
CDIAC's Bookshelf	21
Order Form	24

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CDIAC's Program Manager:  
Wanda Farrell

## Director's Desk

From the

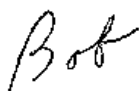
Many staff changes have taken place at ORNL since late last year, and CDIAC has not been immune. Some long-time CDIAC staff have retired or moved to other projects, and some new (and not-so-new) faces have joined CDIAC. Of course, people and their talents are not interchangeable, so when staff leave, they take something with them that cannot be replaced. In response, we restructure the way we approach our work, and we try to take advantage of the unique abilities of our revised team.

During the past few months, CDIAC lost the services of Linda Allison, Marvel Burtis, Susan Holladay, and Gloria Taylor. Linda, who retired, was a former CDIAC staff member, who helped produce one of our earliest—and still one of our most requested—data products: the Olson et al. database of carbon in global ecosystems (<http://cdiac.esd.ornl.gov/ndps/ndp017.html>). More recently, Linda worked on a number of varied data products, including several databases of ocean carbon (<http://cdiac.esd.ornl.gov/oceans/home.html>). Marvel, who also retired, was a mainstay of CDIAC's Information Services Group. Marvel's talents were especially instrumental in the publication of the Russian-English (<http://cdiac.esd.ornl.gov/epubs/cdiac/russengl.html>) and the Chinese-English (<http://cdiac.esd.ornl.gov/epubs/cdiac/cdiac117/cdiac117.html>) global climate-change bibliographies. Susan, who worked on the AmeriFlux data management project (<http://cdiac.esd.ornl.gov/programs/ameriflux/>), moved to the related FLUXNET data management project. Gloria Taylor, CDIAC's hardworking secretary, moved to a different section in our division—our loss and the division's gain. All four will be missed!

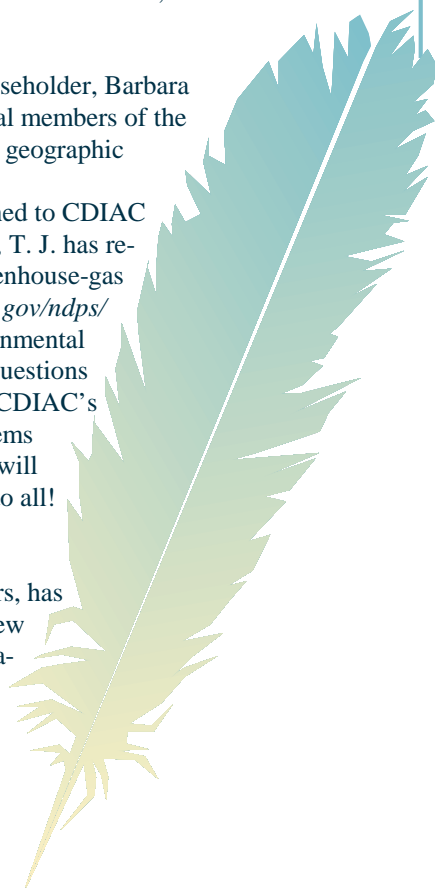
Another of CDIAC's Information Services group mainstays, Karen Gibson, transferred to the ARM Archive to replace a former CDIAC staff member, Debbie Shepherd (who also retired from that DOE data center). Karen helped publish the print and online versions of many data and information products, and she responded to user requests. Fortunately, CDIAC will be retaining Karen's abilities as co-editor of our newsletter, *CDIAC Communications* (<http://cdiac.esd.ornl.gov/newsletr/ccindex.html>)!

On the bright side, Tammy Beaty, T. J. Blasing, Gerry Eddlemon, Carolyn Householder, Barbara Jackson, and Lisa Olsen recently joined CDIAC. Tammy was one of the original members of the data center, and many users will associate her name with CDIAC's early use of geographic information systems and, in particular, the global coastal hazards databases (e.g., <http://cdiac.esd.ornl.gov/epubs/ndp/ndp043c/43c.htm>). Tammy has returned to CDIAC primarily to focus on ocean carbon data management. An atmospheric scientist, T. J. has returned to our division from the ORNL Energy Division and will work with greenhouse-gas data (you may recall his publications of tree-ring data; see <http://cdiac.esd.ornl.gov/ndps/ndp002.html> and <http://cdiac.esd.ornl.gov/ndps/db1005.html>). Gerry, an environmental scientist, has joined our Information Services Group to help answer scientific questions from users. Carolyn is also in our Information Services Group and will handle CDIAC's secretarial tasks. Barbara, a computer scientist, will work on the computer systems underlying the AmeriFlux data management system. Lisa Olsen, a geographer, will enhance the user interfaces of some of our spatial databases. Welcome aboard to all!

Not all the changes affecting CDIAC have taken place in Oak Ridge. With regret, I note that Bobbi Parra, CDIAC's program manager at DOE headquarters, has left DOE for a position in the private sector. But I am pleased to add that our new DOE program manager is Wanda Ferrell, who has long represented DOE's data-management interests in the U.S. Global Change Research Program.



Robert M. Cushman

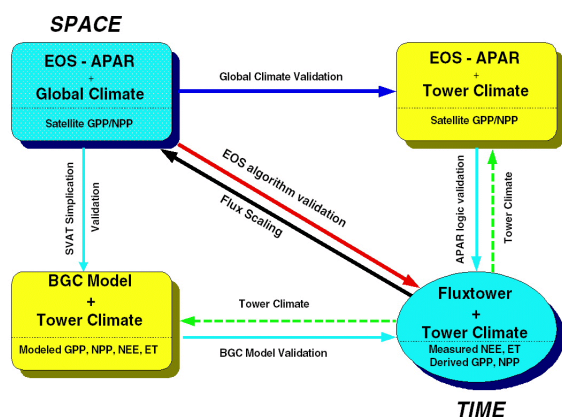


# CDIAC's AmeriFlux Data Archive Supports Real-Time Data Evaluation Exercise

by Tom Boden

CDIAC serves as the long-term repository for measurements collected by the AmeriFlux network (<http://cdiac.esd.ornl.gov/programs/ameriflux/>). AmeriFlux consists of approximately 45 sites throughout North, Central, and South America that make continuous, long-term measurements of carbon dioxide, water, and energy exchange from a variety of ecosystems. One of the on-going justifications for the AmeriFlux network is the opportunity to provide site-specific calibration and verification data for models and satellite data. Since October 2000, CDIAC has posted weekly micrometeorological data from participating AmeriFlux sites for an evaluation exercise initiated by Dr. Steve Running of the University of Montana, Numerical Terradynamic Simulation Group (NTSG).

## FLUX TOWER BASED VALIDATION FOR MODIS GPP/NPP



Every week during this voluntary exercise, AmeriFlux sites have provided canopy-top micrometeorological data reported on half-hourly or hourly time intervals for use in models. The micrometeorological data include air temperature, precipitation, relative humidity, photosynthetically active radiation (PAR) or incident solar radiation, and wind speed. In return, participating modeling groups must

submit weekly their model estimates for site-specific, daily evapo-transpiration (ET), gross primary productivity (GPP), net ecosystem exchange (NEE), and net primary productivity (NPP) for the AmeriFlux scientists to compare with their own productivity estimates and NEE measurements. An important element of this exercise is that the modeling groups provide the model estimates of ET, GPP, NEE, and NPP for each site without immediately seeing corresponding estimates measurements from the AmeriFlux scientists.

CDIAC's role in the exercise is to facilitate the transfer of the AmeriFlux real-time micrometeorological data, perform quality checks on the AmeriFlux data, identify and fill gaps in data records to provide continuous time series to the modelers, and post the AmeriFlux data and model results on the Web for easy access by the participating scientists and modeling groups. To aid modelers' efforts to initialize their models for each site, CDIAC has assembled tables containing site information, vegetation characteristics, and carbon and nitrogen pool estimates provided by the AmeriFlux scientists.

Fifteen AmeriFlux sites are presently submitting data to CDIAC. These sites collectively offer impressive spatial, climatic, and ecosystem representation. More AmeriFlux sites are expected to join. To date, eight modeling groups have expressed interest in participating in the evaluation exercise. CDIAC worked with the BIOME-BGC team to automate and streamline the process before officially starting the exercise. Other modeling groups are now preparing to join the exercise (e.g., establishing site-specific initializations), although participation by some modeling groups is contingent on the availability of satellite data products.

As part of this exercise, 8-day, site-specific Moderate Resolution Imaging Spectroradiometer (MODIS) products will be made available to participating AmeriFlux scientists and modeling groups. MODIS is a key instrument aboard the Terra (EOS AM-1) satellite, successfully launched on December 18, 1999. MODIS views the entire Earth's surface every 1 to 2 days. From MODIS images, various data products will be derived, including estimates of leaf area index (LAI), fractional photosynthetically active radiation (FPAR), ET, and NPP. The MODIS products are not yet available but are expected to be available for this exercise

by spring 2001 through NASA's Distributed Active Archive Center (DAAC) at Oak Ridge National Laboratory.

For additional information about the AmeriFlux/model/MODIS validation exercise, visit <http://cdiac.esd.ornl.gov/programs/ameriflux/modelval.htm>, or contact Steve Running (swr@ntsg.umn.edu) or Tom Boden (tab@ornl.gov). Modeling groups wishing to participate must be willing to provide site-specific daily ET, GPP, NEE, and NEP computations each week to CDIAAC for use by participating AmeriFlux measurement groups. ☺



AmeriFlux sites participating in the AmeriFlux/Model/MODIS evaluation exercise.

#### Site (Coordinates)

Barrow, Alaska (70° 18' N, 156° 36' W)  
 Park Falls, Wisconsin (45° 56' N, 90° 16' W)  
 Wind River, Washington (45° 49' N, 12° 57' W)  
 U. of Mich. Biol. Station, Michigan (45° 35' N, 84° 42' W)  
 Howland Forest, Maine (45° 15' N, 68° 45' W)  
 Metolius, Oregon (44° 25' N, 121° 34' W)  
 Harvard Forest, Massachusetts (42° 32' N, 72° 11' W)  
 Morgan Monroe State Forest, Indiana (39° 19' N, 86° 25' W)  
 Walker Branch, Tennessee (35° 52' N, 79° 59' W)  
 Blodgett Forest, California (38° 53' N, 120° 37' W)  
 Shidler, Oklahoma (36° 56' N, 96° 41' W)  
 Ponca, Oklahoma (36° 46' N, 97° 08' W)  
 Sky Oaks, California (33° 22' N, 116° 37' W)  
 La Selva, Costa Rica (10° 26' N, 83° 59' W)  
 Kruger Park, South Africa (25° 1' S, 31° 29' E)

#### Vegetation Type (age)

Arctic tundra (8000–10,000 years)  
 Temperate/boreal, lowland and wetland forest (40–80 years)  
 Temperate rain forest (400–500 years)  
 Northern deciduous hardwoods/conifers (90 years)  
 Sub-boreal evergreen (90 years)  
 Temperate coniferous (20 years)  
 Temperate mixed deciduous (70 years)  
 Mixed deciduous hardwoods (60–80 year)  
 Mixed deciduous and broad-leaved (60 years)  
 Ponderosa pine plantation (7–8 year)  
 Native tallgrass prairie  
 Winter wheat  
 Chaparral (2 sites, 4 & 78 years)  
 Tropical wet forest (>400 years)  
 Savanna [2 sites: Acacia and Combretum - recent burn]



# Trends Online Additions and Updates

## Atmospheric Trace Gas Concentrations

### *Carbon Dioxide and Carbon Isotopes*

**Atmospheric CO<sub>2</sub> Records from Sites in the SIO Air Sampling Network** (*C. D. Keeling and T. P. Whorf*)  
(<http://cdiac.esd.ornl.gov/trends/co2/sio-keel.htm>)

Ambient atmospheric CO<sub>2</sub> data from the Mauna Loa Observatory, Mauna Loa, Hawaii; Barrow, Alaska; Cape Matatula, American Samoa; and the South Pole have been updated through 1999. All digital data, figures, and documentation are available in *Trends Online*.

The ambient atmospheric CO<sub>2</sub> measurements taken at the Mauna Loa Observatory since 1958 constitute the longest continuous record of atmospheric CO<sub>2</sub> concentrations available in the world. The Mauna Loa site is considered one of the most favorable locations for measuring undisturbed air because the possible local influences of vegetation or human activities on atmospheric CO<sub>2</sub> concentrations are minimal and any influences from volcanic vents may be excluded from the records. The methods and equipment used to obtain these measurements have remained essentially unchanged during the 40-plus years of the monitoring program.

Between 1959 and 1999, the Mauna Loa record shows a 16.6% rise in the mean annual concentration, increasing from 315.83 parts per million by volume (ppmv) of dry air to 368.37 ppmv. A 2.9-ppmv increase in mean annual concentration from 1997 to 1998 represents the largest single yearly jump since the Mauna Loa record began in 1958; the 1998–99 increase in mean annual concentration was 1.67 ppmv.

Since 1974, the annual average CO<sub>2</sub> concentration at Barrow has risen from 332.60 ppmv to 369.68 ppmv in 1999 (constituting an annual increase of 1.4 ppmv). The Barrow record is indicative of maritime air masses and shows the large seasonal amplitude typical for high latitude northern sites.

At Cape Matatula, the annual concentration of CO<sub>2</sub> rose from 340.43 ppmv in 1982 to 367.02 ppmv in 1999 (displaying an annual growth rate of ~1.5 ppmv). At the South Pole, the annual CO<sub>2</sub> concentration rose from 327.45 ppmv in 1973 to 365.69 ppmv in 1999 (constituting an annual increase of >1.4 ppmv).

The Mauna Loa data are also available in NDP-001. For more details see page 16 or visit our Web site (<http://cdiac.esd.ornl.gov/ndps/ndp001.html>). ☺

### *Other Atmospheric Trace Gases*

**Trifluoromethyl Sulfur Pentafluoride (SF<sub>5</sub>CF<sub>3</sub>) and Sulfur Hexafluoride (SF<sub>6</sub>) from Dome Concordia** (*W. T. Sturges et al.*)  
(<http://cdiac.esd.ornl.gov/trends/otheratg/sturges/sturges.html>)

Air samples were pumped from consolidated deep snow (i.e., firn) at Dome Concordia in eastern Antarctica in December 1998 and January 1999 from the surface to a depth of approximately 100 m. Air samples were analyzed with a gas chromatograph–mass spectrometer, with a detection limit of about 0.001 parts per trillion (ppt). A diffusive transport model was used to calculate the age of the samples as a function of depth. Measurements of SF<sub>6</sub> were used to determine the mean age of the firn air by comparison with extrapolated measurements from Cape Grim, Tasmania, combined with estimates from industrial emissions. Dates for SF<sub>5</sub>CF<sub>3</sub> are different than those for SF<sub>6</sub> because of the lower diffusivity of SF<sub>5</sub>CF<sub>3</sub>. The SF<sub>6</sub> ages

were multiplied by the ratio of the free-air diffusion coefficient of  $\text{SF}_5\text{CF}_3$  to that of  $\text{SF}_6$  (1.18). Free-air diffusion coefficients were determined by a semi-empirical formula based on molecular volumes. Note that mean ages represent a wide distribution of probable ages spanning many years, with an increasing spread of ages at increasing depth.

The measured concentration of  $\text{SF}_5\text{CF}_3$  increased from zero in 1965–1966 to about 0.12 ppt in 1999, with a current growth rate of about 0.008 ppt per year (about 6% per year). The similarity of the growth curves of  $\text{SF}_5\text{CF}_3$  and  $\text{SF}_6$  (which increased from 0.18 ppt in 1970 to 4.0 ppt in 1999) indicates that the former may originate as a breakdown product of the latter in high-voltage equipment. While the current radiative forcing of  $\text{SF}_5\text{CF}_3$  may be minor, the high growth rate and long atmospheric residence time suggest that the greenhouse significance of this gas could increase markedly in the future. On the other hand,  $\text{SF}_5\text{CF}_3$  appears not to have any natural sources, so control might be feasible, once the sources are identified. ☹

**Atmospheric Fluoroform ( $\text{CHF}_3$ , HFC-23) at Cape Grim, Tasmania** (*D. E. Oram et al.*) (<http://cdiac.esd.ornl.gov/trends/otheratg/oram/oram.html>)

Air samples were taken from the archive of Cape Grim, Tasmania, from samples collected during 1978 through 1995. Comparisons of CFC-11, CFC-12, CFC-113,  $\text{CH}_3\text{CCl}_3$ , and  $\text{CH}_4$  data between archive samples and corresponding in situ samples for the same dates confirm that the archive samples are both representative and stable over time. Samples were analyzed by gas chromatography–mass spectrometry (GC-MS) using a KCl-passivated alumina PLOT column. Fluoroform was monitored on mass 69 ( $\text{CF}_3^+$ ). The analytical precision (one standard deviation of the mean) for two or three replicate analyses was typically  $\pm 1\%$  of the mean measured value. The overall uncertainty of the observed data was  $\pm 10\%$ , taking into account uncertainties in the preparation of the primary standards, the purity of the fluoroform

used to make the primary standards, and the analytical precision.

The measured concentration of fluoroform at Cape Grim increased from  $\sim 2$  pptv in early 1978 to  $\sim 11$  pptv by late 1995. The growth rate was 0.55 pptv per year over the period 1990–1995, or about 5% per year relative to the late 1995 value. ☹

## Greenhouse Gas Emissions

### *Carbon Dioxide Emissions from Fossil-Fuel Consumption*

**Global, Regional, and National Fossil-Fuel  $\text{CO}_2$  Emissions** (*G. Marland et al.*) ([http://cdiac.esd.ornl.gov/trends/emis/em\\_cont.htm](http://cdiac.esd.ornl.gov/trends/emis/em_cont.htm))

CDIAC's estimates of global, regional, and national  $\text{CO}_2$  emissions from fossil-fuel combustion and cement production extend from 1751–1997. The 1997 global  $\text{CO}_2$  emissions estimate of 6601 million metric tons of carbon is the highest fossil-fuel emission estimate ever. The 1997 estimate represents a 1.3% increase over 1996, continuing a trend of modest growth since a 1991–1993 decline in global  $\text{CO}_2$  emissions.

These data are also available in NDP-030. For more details see page 17 or visit our Web site (<http://cdiac.esd.ornl.gov/ndps/ndp030.html>). ☹

### *Carbon Flux from Land-Cover Change*

**Carbon Flux to the Atmosphere from Land-Use Changes** (*R. A. Houghton and J. L. Hackler*) (<http://cdiac.esd.ornl.gov/trends/landuse/houghton/houghton.html>)

In the attempt to “balance” the global carbon cycle (that is, reconcile the known sources and sinks of carbon) there have been two major unknowns: the flux between the atmosphere and the oceans and the flux between the atmosphere

and terrestrial ecosystems. To address the latter, several investigators have attempted to estimate the flows of carbon between the atmosphere and both temperate and tropical ecosystems. The database presented here provides estimates of regional and global net carbon fluxes on a yearly basis from 1850 through 1990 as a result of changes in land use (such as harvesting of forest products and clearing for agriculture). These estimates take into account not only the initial removal and oxidation of the carbon in the vegetation but also subsequent regrowth and changes in soil carbon.

The net flux of carbon to the atmosphere from changes in land use from 1850 to 1990 was modeled as a function of documented land use change and alterations in aboveground and belowground carbon following changes in land use. The changes in carbon over time following land use change are specified by region and ecosystem type.

These estimates indicate that the global total net flux from 1850 through 1990 was 124 petagrams (1 Pg =  $10^{15}$  g) of carbon. For the year 1990, the global total net flux was estimated to be 2.1 Pg of carbon; in comparison, the estimated 1990 carbon flux to the atmosphere from fossil-fuel combustion and cement production has been estimated at 6.1 Pg of carbon. ☺

## Climate

### Temperature

#### Global and Hemispheric Temperature Anomalies—Land and Marine Instrumental Records (*P. D. Jones et al.*)

(<http://cdiac.esd.ornl.gov/trends/temp/jonescru/jones.html>)

These global and hemispheric temperature anomaly time series, which incorporate land and marine data, are continually updated and expanded. Some of the earliest work in producing these temperature series dates back to 1886.

The land portion of the database from which the time series are computed consists of surface air temperature (SAT) data (land-surface meteorological data and fixed-position weather ship data) that have been corrected for nonclimatic errors, such as station shifts and/or instrument changes. The most recent reanalysis of land surface data by the Climatic Research Unit (CRU) resulted in (1) the inclusion of over 1000 additional stations, (2) a new reference period common to all stations (1961–1990; previously 1950–1979), and (3) increased grid-box resolution of the temperature anomalies ( $5^\circ \times 5^\circ$ ). The marine data used in the present analysis are compiled at the Hadley Centre of the United Kingdom Meteorological Office and consist of sea surface temperatures (SSTs) that incorporate in situ measurements from ships and buoys. The SST data have been corrected to eliminate effects of using different types of buckets used before 1942. These SSTs also were converted to anomalies with respect to the 1961–1990 mean, and the two constituent data sets (SAT and SST) were combined.

The resulting data set has been used extensively in Intergovernmental Panel on Climate Change (IPCC) reports in which the global-mean temperature changes evident in the record have been interpreted in terms of anthropogenic forcing influences and natural variability.

Trends in annual mean temperature anomalies for the globe show relatively stable temperatures from the beginning of the record through about 1910, with relatively rapid and steady warming through the early 1940s, followed by another period of relatively stable temperatures through the mid-1970s. Since then, rapid rise is observed similar to that in the earlier part of the century. The year 1998 was the warmest year in the global mean temperature series, followed by 1997. The year 1998's anomaly was  $0.57^\circ\text{C}$  above the mean temperature of the 1961–1990 reference period. [Jones et al. (1999) report  $14.0^\circ\text{C}$ ,  $14.6^\circ\text{C}$ , and  $13.4^\circ\text{C}$  as the means for the globe, northern hemisphere, and southern hemisphere, respectively, during the 1961–1990 reference period].

The most recent year of the record, 1999, also saw a significant positive temperature anomaly ( $0.33^{\circ}\text{C}$ ) but represents a cooling in comparison with the two previous years, in large part because of the transition from El Niño conditions during parts of 1997 and 1998 to La Niña conditions in 1999. Nevertheless, 1999 ranks as the fifth warmest year in the global record, and the seven warmest years of the global record have occurred since 1990. They are, in descending order, 1998, 1997, 1995, 1990, 1999, 1991, and 1994. ☺

### Global, Hemispheric, and Zonal Temperature Deviations Derived from Radiosonde Records (J. K. Angell)

(<http://cdiac.esd.ornl.gov/trends/temp/angell/angell.html>)

Data from a global network of 63 radiosonde stations were used to estimate global, hemispheric, and zonal annual and seasonal temperature deviations from 1958 through 1999. These estimates are categorized vertically (for the surface, troposphere, tropopause, low stratosphere, and the surface up to 100 mb) and horizontally (for the globe, the northern and southern

hemispheres, the north and south polar, North and South temperate, North and South subtropical, tropical, and equatorial latitudinal zones).

The data were obtained from values published in *Monthly Climatic Data for the World* and *Climatic Data for the World*, from the Global Telecommunications System (GTS) Network, and from National Center for Atmospheric Research files. On the basis of data from this network, Angell reported that during 1958–1999 the global, near-surface air temperature warmed  $0.14^{\circ}\text{C}$  per decade and the troposphere layer warmed  $0.10^{\circ}\text{C}$  per decade. The tropopause cooled in the extra tropics but warmed slightly in the tropics. The low-stratospheric layer cooled by about  $0.4^{\circ}\text{C}$  per decade in the tropics and extratropics. At both the surface and in the troposphere, 1998 was the warmest year of the 41-year record, but when the influence of the powerful El Niño of 1997–1998 is taken into account, 1990 remains the warmest year of the record.

These data are also available in NDP-008. For more details see page 16 or visit our Web site (<http://cdiac.esd.ornl.gov/ndps/ndp008.html>). ☺

## Carbon Sequestration Web Site



In the past 60 years, the amount of anthropogenic  $\text{CO}_2$  emitted to the atmosphere, primarily because of expanding use of fossil fuels for energy, has risen from the pre-industrial level, at 280 parts per million (ppm),

to the present level, at  $>368$  ppm. Predictions of global energy use in the next century suggest a continued increase in carbon emissions and increasing concentrations of  $\text{CO}_2$  in the atmosphere unless major changes are made in the way we produce and use energy—in particular, how we manage carbon. One way to manage carbon

is to use energy more efficiently and thereby reduce our need for a major source of energy and carbon, namely, fossil fuel combustion. Another way is to increase our use of low-carbon and carbon-free fuels and technologies (i.e., nuclear power and renewable sources such as solar energy, wind power, and biomass fuels). Both approaches are supported by DOE. The third and newest way to manage carbon is through carbon sequestration.

“Carbon sequestration” refers to the long-term storage of carbon in the terrestrial biosphere, in the ground, or in the oceans so that the buildup of carbon dioxide—the principal anthropogenic greenhouse gas—in the atmosphere will be reduced or delayed. In some cases, the reduction

or delay is accomplished by maintaining or enhancing natural processes; in other cases, novel techniques are developed to dispose of carbon. DOE's Office of Science is focusing efforts on the following:

- sequestering carbon in underground geologic repositories
- enhancing the natural terrestrial cycle
- carbon sequestration in the oceans, and
- sequencing genomes of micro-organisms for carbon management

We need to understand how carbon dioxide "sinks," or storage places, perform so we can

enhance the ongoing natural processes and develop innovative new processes. Such developments may add powerful new measures to carbon management options.

Midyear in 2000, CDIAC launched the DOE Office of Science's Carbon Sequestration Web site (<http://cdiac2.esd.ornl.gov/>). Developed by Karen Gibson, the site offers links to the three DOE carbon sequestration centers, provides DOE contacts and DOE reports related to carbon sequestration, and offers information on related meetings and seminars, news, and research opportunities. ☺

## Focus Areas

### **FACE** Free-Air CO<sub>2</sub> Enrichment

CDIAC Director, Robert Cushman, presented the poster "Data and Information Management for FACE" at the FACE (Free-Air CO<sub>2</sub> Enrichment) 2000 Conference in Tsukuba, Japan. The poster illustrated data management tasks performed at CDIAC (i.e., data compilation, reformatting, quality-assurance, documentation, and distribution). It also showed the role of standardization of variable names and units in facilitating syntheses and analyses across the global network of approximately 30 FACE sites. In addition, the poster gave examples of the information available from CDIAC's FACE Web site (<http://cdiac.esd.ornl.gov/programs/FACE/face.html>). ☺



### Global Change Climate Data

**Assessing Observed Temperature and Cloud Amount Trends for China over the Last Half of the Twentieth Century: What Can the Sunshine Duration Record Tell Us?**

CDIAC's Dale Kaiser presented the paper "Assessing Observed Temperature and Cloud

Amount Trends for China over the Last Half of the Twentieth Century: What Can the Sunshine Duration Record Tell Us?" at the 81st Annual Meeting of the American Meteorological Society and 12th Symposium on Global Change and Climate Variations held in Albuquerque, New Mexico. Dale described a large observed decrease in sunshine duration over most of China from 1954 to 1998, even though cloud amount is also decreasing significantly over most of the country. The most likely explanation for such a paradox is that the atmosphere over China is becoming so polluted with sunshine-reflecting aerosols (mainly anthropogenic) that the sunshine recording instrument senses less direct bright sunshine. Decreases in sunshine duration are thought to be the leading cause of anomalous cooling in maximum temperatures observed over a region centered on Sichuan Province (mainly in summer). In China, because of the aerosol effect, sunshine duration cannot be used as a proxy for cloud amount. This analysis stems from CDIAC's involvement in a bilateral research agreement between DOE and the China Meteorological Administration (CMA) examining regional climate changes. ☺

## Decreasing Cloudiness over China: An Updated Analysis Examining Additional Variables

Dale Kaiser also published “Decreasing Cloudiness over China: An Updated Analysis Examining Additional Variables” in the journal *Geophysical Research Letters* (GRL) (Vol. 27, No. 15, pp. 2193–2196). Versions of the paper are available in HTML and PDF format from the American Geophysical Union Web site (<http://www.agu.org/>). The paper is an update and expansion of the first GRL paper Dale authored on the subject in 1998 (<http://www.agu.org/>). Both studies make use of six-hourly weather observations provided to CDIAC by the CMA through a bilateral research agreement with DOE. The current paper adds two years to the cloud amount series (1995 and 1996), using cloud data from the global database compiled by Hahn and Warren in 1999

(<http://cdiac.esd.ornl.gov/epubs/ndp/ndp026c/ndp026c.html>), and shows that the marked decreasing trend in all-China mean cloud amount has continued. The study also analyzes trends in station pressure, water vapor pressure, and relative humidity. Several key findings emerged. Annual mean station pressure has increased dramatically over most of China, and annual mean water vapor pressure has increased significantly in northwest and east-central China (no areas show any significant decreases). Relative humidity has decreased significantly in the northeast (where the largest decreases in cloud amount are observed) but has increased significantly in the northwest (consistent with water vapor increases). Especially interesting is the concomitant sudden decrease in the nationwide cloud amount series around 1978 and the sudden increase in station pressure. These changes coincide closely with the large increase in global mean temperature (mainly driven by increasing daily minimum temperature), which in turn coincides with what the IPCC has described as a fundamental shift in the El Niño/Southern Oscillation (ENSO) phenomenon about that time (i.e., relatively more frequent El Niño episodes in comparison with La Niña episodes). ☺



## NARSTO

Les Hook and Meng-Dawn Cheng represented CDIAC's NARSTO Quality Systems Science Center (<http://cdiac.esd.ornl.gov/programs/NARSTO/>) at the NARSTO 2000 meeting, “Tropospheric Aerosols Science and Decisions in an International Community,” held in Queretaro, Mexico. Les co-chaired the Data Management/ Quality session. He presented a paper “The NARSTO Data and Information Sharing Tool” and displayed a poster “The Truth about Data Management” (both co-authored with Sigurd Christensen). In the session on Stationary Sources/Controls, Meng-Dawn presented “Real-Time Emission Measurement of Fine Particulates and Heavy Metals” (co-authored with Madhavi Martin and Thomas Wainman, also of the ORNL Environmental Sciences Division). ☺



## Ocean Data

CDIAC's Alex Kozyr attended the PICES (the North Pacific Marine Science Organization) CO<sub>2</sub> Data Integration Test Workshop in Sidney, British Columbia, and participated in discussions on the synthesis of ocean CO<sub>2</sub> data from the North Pacific region. The workshop included representatives from Canada, Japan, and the United States. Among the recommendations of the workshop was the compilation of an International North Pacific Data Inventory for CO<sub>2</sub> and CO<sub>2</sub>-related data. A follow-up CO<sub>2</sub> Data Integration Implementation Workshop is planned for Tokyo in May 2001.

Alex also represented CDIAC's ocean carbon effort at two meetings in Japan sponsored by the PICES: the Symposium on North Pacific CO<sub>2</sub> Data Synthesis (in Tsukuba) and the session on North Pacific carbon cycling and ecosystem dynamics as part of the PICES Ninth Annual Meeting (in Hakodate). Alex presented the new CDIAC data access through Web maps and described the new CDIAC - World Ocean Circulation Experiment (WOCE) Collection that

he created using the Ocean Data View Program (to be available shortly through the CDIAC's Ocean Web site (<http://cdiac.esd.ornl.gov/oceans/home.html>)). ☺

## Other

Bob Cushman presented the talk "All The Greenhouse Gases—Where Do They All Come

From?" at the DOE Global Change Education Program End-of-Summer Workshop in Oak Ridge, Tennessee. The talk discussed the many sources of greenhouse gases, differences in relative contributions of the various gases and contributing sources as a function of spatial scale (from global through sub-national), and issues in adding emissions inventories to yield inventories for larger scales. ☺

## energy.gov Open for Business



DOE embraced a new way of doing business on the Web with the introduction of the *energy.gov* Web site early last fall. After running in parallel with the *doe.gov* Web site for its first few weeks, *energy.gov* became the new home page for the DOE on October 2, 2000.

"The new site will mark a major step in the Department's efforts to implement e-government initiatives and in fulfilling former Secretary Richardson's commitment to meeting the needs of our most important customers – the American public," predicted Mark Mazur, the Acting Administrator for the Energy Information Administration (EIA).

Flipping the switch to *energy.gov* culminated a nine-month effort by a cross cutting team at DOE called the Web Forum. Their task was to build an improved Web site for DOE. The project was led by the Consumer Information Office and the Chief Information Office in response to Secretary Richardson's vision that the agency's work be better understood by the public we serve.

"The problem is not that what we do is not meaningful to people," said Consumer Information Director Kathy McShea, whose office was opened as a secretarial initiative to help DOE make a better connection with the American people. "The problem was that too many people couldn't find us or our information. We hope *energy.gov* helps address

that problem by adopting a more consumer-friendly approach to Web design that puts the customer first."

When a group of Web professionals from each program office were invited to help build the *energy.gov* Web site in late 1999, they quickly embraced the initiative as their own. They started by creating a new navigation system to categorize DOE's rich, Web-based resources in a topical way, instead of allowing it to be mired in government speak. Then they selected a design that best met the project's goals. Once these decisions came into place, there was no looking back. The result is a site that better informs the public with energy information tools that can save them money and power their world.

If the problem is that too many people don't know what DOE does, the answer is the Web site, with the bright banner that says "the Energy that Surrounds You."

"All too often DOE accomplishments in all fields of endeavor are overlooked or ignored," said James Decker, Principal Deputy Director for the Office of Science. "The Internet can be a powerful tool to help rectify that problem... To keep up with an increasingly competitive information marketplace, the Department of Energy would do well to embrace *energy.gov*." A primary navigation bar is designed for the new visitor who wants to learn something about

DOE and explore its information resources. It divides the content into everyday terms such as “Your Health,” “Your House,” “Your Transportation,” or “Your World.” Each of these pages will feature a different page each month, meant to promote the best on the Web from DOE that month.

A secondary navigation bar is built with the regular visitor in mind – those who know what they are looking for. It is broken into three sections.

The first section, “inside the DOE,” contains DOE’s highly trafficked internal pages like the press area and the jobs site. The second section, “Energy and...,” builds content in the popular “Yahoo” style on the theory that people have different ways of searching for information but ought to be able to get to the same place no matter which door they enter. The third section, “Resources,” includes access to over 100 online subscriptions and a publication center with over 120 of DOE’s “bestsellers,” as well as databases, photo galleries, and online software.

Selecting the content of the site and navigation bar was a critical step in the process of building *energy.gov*. It was accomplished by a “gold diggers” club, which helped the Web Forum identify the most popular DOE Web sites. In the future, a newly established “Web Council” will maintain the site and keep the content fresh and current.

The *energy.gov* site has a clean look and feel that belies the fact that it provides links to over 800 different Web sites – a powerful resource for consumers and DOE employees alike to make the most of Web-based tools.

“The appearance, depth of content, and most importantly, the consumer-friendly approach, will make the new design an excellent portal to the wealth of electronic information available throughout the DOE complex,” said Robert Kripowicz, Acting Director for the Office of Fossil Energy. “We look forward to seeing the new site become the main Internet entry point for DOE.” ☺

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## Carbon Emitted, Carbon Saved

*Continued from p. 1*

Although the United States could reduce its CO<sub>2</sub> emissions by more than 4% by prohibiting oil refineries in this country and importing refined petroleum products instead, there would be no savings in the overall global emissions because the refineries would simply be moved to another country. The data show that CO<sub>2</sub> emissions from the United States amount to 5.4 metric tons of carbon per person per year, but most people would find that their personal inventory of emissions is far less than that. Their inventory results primarily from the gasoline used by their car and the natural gas used by their furnace or hot water heater. Most of the 5.4 tons of carbon comes from electric power plants that power our homes, factories, and shopping centers; from factories that produce our clothes and other consumer goods; from tractors on farms; from

trucks that deliver materials to factories and finished products to stores; from gas grills at local restaurants; and so forth.

Because of our interdependence, a ton of carbon emissions avoided can lead to more or less than a ton of carbon emissions saved. Data from the U.S. Office of Technology Assessment (1990) suggest that 1.16 liters of petroleum products are needed to deliver 1 liter of gasoline to the final consumer. Not burning a liter of gasoline save 0.64 kg of carbon in emissions from the automobile and also save emissions from the fuel truck, the refinery, and the petroleum production system. Furthermore, although an automobile factory might require more energy and thus involve more CO<sub>2</sub> emissions to produce an energy-efficient automobile, every person who purchased one of the automobiles would save energy and CO<sub>2</sub> emissions. Nevertheless, one further step must be considered: If automobile

drivers could drive the same distance for less gasoline, might they be tempted to drive more?

It may be possible to reduce net emissions of carbon to the atmosphere by increasing the uptake and storage of carbon in plants and soils. But, it is necessary to consider systems boundaries. An extra ton of carbon stored in the soil does not necessarily imply one ton of carbon would be saved from the atmosphere. Recent analysis (West and Marland, 2001) suggests that changing from conventional tillage to no-till agriculture (based on average U.S. practice) can result in storing more carbon in the soil and save carbon emissions because less fuel is used on the farm. In this case, putting a ton of carbon into the soil can save more than a ton of carbon from the atmosphere. On the other hand, if putting a ton of carbon in the soil required more on-farm fuel or more nitrogen fertilizer (which requires fossil fuels for its production), then putting a ton of carbon in the soil save less than a ton of carbon from the atmosphere. Use of additional nitrogen fertilizer might also affect emissions of N<sub>2</sub>O, another greenhouse gas.

Carbon can also be removed from the atmosphere by photosynthesis and stored in trees, and this increase in forest carbon can be measured with appropriate inventory techniques. These inventory techniques must account for the time dimension inherent in the life cycle of trees in both managed and unmanaged forest stands. What the inventory will not show is the impact that increasing carbon storage in the forest has on the management of other forests, the flow of forest products, or the substitution of forest products by other (often more energy-intensive) products. Analyses of forestry projects by Marland and Schlamadinger (1997) have tried to broaden the system boundaries to make sure that the full, appropriate system is considered when the intent is to save CO<sub>2</sub> emissions.

Efforts to analyze CO<sub>2</sub> emissions from the pulp and paper industry have employed a mass balance approach to try to estimate carbon

emissions. As wood is harvested, fiber moves through the chain of paper production and use, and fossil fuels are consumed to power the processes. Mass balances for the raw materials and fuels can provide an inventory of CO<sub>2</sub> emissions from the processing, but an analysis of the effect of pulp and paper processing on carbon emissions to the atmosphere requires an understanding of where and how the wood was harvested; whether any by-products were generated; and the product's use, recycle, and disposal.

The bottom line is that it is relatively straightforward to do an emissions inventory, although care is needed to define appropriate and consistent system boundaries in terms of time and space. It is not so easy to determine how much greenhouse gas emissions are changed as a result of a change in human behavior. A ton of carbon not emitted is not necessarily a ton saved.

The recently emerging concept of carbon management has far-reaching implications beyond an inventory of "your carbon" and "my carbon." It encompasses the broad array of activities that involve our management of the biosphere, our use of energy, and the complex linkages that tie them together.

## References

- Marland, G., and B. Schlamadinger. 1997. Forests for Carbon Sequestration or Fossil Fuel Substitution? A Sensitivity Analysis. *Biomass and Bioenergy* 13: 389–397.
- U.S. Office of Technology Assessment. 1990. *Energy Use and the U.S. Economy*. OTA-BP-E-57. U.S. Government Printing Office, Washington, D.C.
- West, T.O., and G. Marland. 2001. A synthesis of carbon sequestration, carbon emissions, and net carbon flux in agriculture comparing tillage practices in the United States. *Agriculture, Ecosystems and Environment* (*in press*). ☉

## New and Updated CDIAC Products

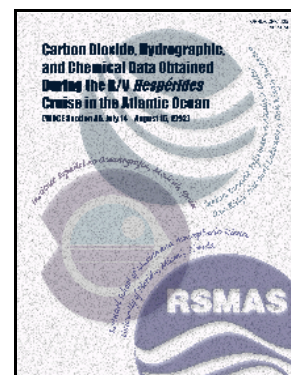
CDIAC's carbon dioxide-related products provide coverage in a number of areas relevant to the greenhouse effect and global climate change. These areas include records of the concentration of CO<sub>2</sub> and other radiatively active gases in the atmosphere; the role of the terrestrial biosphere and the oceans in the biogeochemical cycles of greenhouse gases; emissions of CO<sub>2</sub> to the atmosphere; long-term climate trends; the effects of elevated CO<sub>2</sub> on vegetation; and the vulnerability of coastal areas to rising sea level. All recently released carbon dioxide-related products, new or updated, are described in this section.

CDIAC packages and releases our holdings in form of data products—numeric data packages (NDPs), a computer model package (CMP), and databases—and publications. All of our products are provided free of charge. The printed publications are available from CDIAC while supplies last. Data files and documentation (text or HTML version) that accompany the data products may be accessed and downloaded from CDIAC's Web site (<http://cdiac.esd.ornl.gov/>), from CDIAC's anonymous FTP area ([cdiac.esd.ornl.gov](ftp://cdiac.esd.ornl.gov)), or requested directly from CDIAC on various types of media (e.g., CD-ROM, floppy diskette). All technical questions, such as questions about methodology or accuracy), should be directed to the CDIAC staff member who is responsible for preparing the individual data products.

Note: As the supply of certain CDIAC publications become exhausted, those publications will no longer be distributed by CDIAC. DOE personnel and DOE contractors can request copies from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831 (<http://www.osti.gov/>). Other individuals should contact the National Technical Information Service (703-487-4650) or (<http://www.ntis.gov/>).

### Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V *Hesperides* Cruise in the Atlantic Ocean (WOCE Section A5, July 14–August 15, 1992)

Millero, Frank J., Sara Fiol, and Douglas M. Campbell, Rosenstiel School of Marine and Atmospheric Science, University of Miami; and Gregorio Parrilla, Instituto Español de Oceanografía, Madrid  
Prepared by Linda Allison and Alexander Kozyr, CDIAC



NDP-074 (2000) ([http://cdiac.esd.ornl.gov/oceans/ndp\\_074/ndp074.html](http://cdiac.esd.ornl.gov/oceans/ndp_074/ndp074.html))

The documentation for this data product discusses the procedures and methods used to measure total carbon dioxide (TCO<sub>2</sub>), total alkalinity (TALK), and pH at hydrographic stations during the R/V *Hesperides* oceanographic cruise in the Atlantic Ocean (Section A5). Conducted as part of the World Ocean Circulation Experiment (WOCE), the cruise began in Cadiz, Spain, on July 14, 1992, and ended in Miami, Florida, on August 15, 1992.

Measurements made along WOCE Section A5 [as measured by a conductivity, temperature, and depth sensor (CTD)] included pressure, temperature, salinity, and oxygen; and bottle salinity, oxygen, phosphate, nitrate, nitrite, silicate, TCO<sub>2</sub>, TALK, and pH.

The TALK, TCO<sub>2</sub>, and pH were determined from titrations of seawater collected at 33 stations. The titration systems for measuring

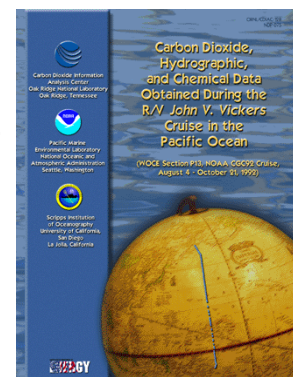
TALK and  $\text{TCO}_2$  were calibrated in the laboratory with certified reference materials (CRMs) before the cruise to ensure traceable results. Standard reference seawater provided by Andrew Dickson of Scripps Institution of Oceanography (SIO) was used at sea to monitor the performance of the titration systems. The results agree with the laboratory results to  $\pm 2 \mu\text{mol/kg}$  for TALK and  $\pm 1 \mu\text{mol/kg}$  for  $\text{TCO}_2$ . The titration systems used to measure pH were calibrated with TRIS seawater buffers prepared in the laboratory and measured with an  $\text{H}_2$ , Pt/AgCl, Ag electrode. The initial electromotive force (emf) of the titrations was used to determine the pH. The values of pH are thought to be reliable to  $\pm 0.01$  and are internally consistent with the measured values of TALK and  $\text{TCO}_2$  to  $\pm 7 \mu\text{mol/kg}$ . The measured carbon dioxide system parameters have been used to

calculate the in situ values of the fugacity of  $\text{CO}_2$  ( $f\text{CO}_2$ ) for the surface water. The surface results are briefly discussed.

WOCE section A5 is located at  $24.5^\circ \text{N}$  along the meridional overturn in the Atlantic Ocean. The maximum heat transfer in the North Atlantic Ocean occurs at  $24^\circ \text{N}$ ; warming in the ocean at this latitude goes down to 3000 m. This section has been studied for a number of years and thus can be used to examine the changes that have occurred in the North Atlantic deep waters. This section has also been studied in the past through inverse methods for looking at the movement of  $\text{CO}_2$  to and from the North Atlantic. The  $\text{CO}_2$ -related measurements aboard the R/V *Hesperides* were supported by DOE. WDC database ☺

## Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V *John V. Vickers* Cruise in the Pacific Ocean (WOCE Section P13, NOAA CGC92 Cruise, August 4–October 21, 1992)

*Dickson, Andrew G., Charles D. Keeling, Peter R. Guenther, Scripps Institution of Oceanography University of California; and John L. Bullister, Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration  
Prepared by Alexander Kozyr, CDIAC*



NDP-075 (2000) ([http://cdiac.esd.ornl.gov/oceans/ndp\\_075/ndp075.html](http://cdiac.esd.ornl.gov/oceans/ndp_075/ndp075.html))

Documentation for this data product discusses the procedures and methods used to measure total carbon dioxide ( $\text{TCO}_2$ ) and total alkalinity (TALK) at hydrographic stations during the R/V *John V. Vickers* oceanographic cruise in the Pacific Ocean (Section P13). Conducted as part of the World Ocean Circulation Experiment (WOCE) and the National Oceanic and Atmospheric Administration's Climate and Global Change Program, the cruise began in Los Angeles, California, on August 4, 1992, with a transit line (Leg 0) to Dutch Harbor, Alaska. On August 16, the ship departed Dutch Harbor on Leg 1 of WOCE section P13. On September 15, the R/V *John V. Vickers* arrived in Kwajalein,

Marshall Islands, for emergency repairs, and after 11 days in port departed for Leg 2 of Section P13 on September 26. The cruise ended on October 21 in Noumea, New Caledonia. Measurements made along WOCE Section P13 included pressure, temperature, salinity [measured by a conductivity, temperature, and depth sensor (CTD)], bottle salinity, bottle oxygen, phosphate, nitrate, nitrite, silicate, chlorofluorocarbons (CFC-11, CFC-12),  $\text{TCO}_2$ , and TALK.

The  $\text{TCO}_2$  was measured by coulometry using a Single-Operator Multiparameter Metabolic Analyzer (SOMMA). The overall precision of

the analyses was  $\pm 2 \mu\text{mol/kg}$ . Samples collected for TALK were measured by potentiometric titration; precision was  $\pm 2 \mu\text{mol/kg}$ . The

CO<sub>2</sub>-related measurements aboard the R/V *John V. Vickers* were supported by DOE. WDC database ☺

## Atmospheric CO<sub>2</sub> Concentrations—Mauna Loa Observatory, Hawaii, 1958–1999 (revised August 2000)

*Keeling, C. D., and T. P. Whorf, Scripps Institution of Oceanography  
Prepared by Tom Boden, CDIAC*

NDP-001 (revised 2000) (<http://cdiac.esd.ornl.gov/ndps/ndp001.html>)

Since 1958, air samples have been continuously collected at Mauna Loa Observatory and analyzed by infrared spectroscopy for CO<sub>2</sub> concentrations. Data are averaged to give monthly and annual atmospheric CO<sub>2</sub> concentrations.

These data represent the longest continuous record of atmospheric CO<sub>2</sub> concentrations in the world. This precise data record covers a single site (Mauna Loa Observatory, Hawaii). It

is a reliable indicator of the regional trend in the concentration of atmospheric CO<sub>2</sub> in the middle layers of the troposphere and is critical to CO<sub>2</sub>-related research

Additional information, including updated methods, trends, and graphics, is described in CDIAC's *Trends Online*. For more details see page 5 or visit our Web site (<http://cdiac.esd.ornl.gov/trends/co2/sio-mlo.htm>). ☺

## Annual and Seasonal Global Temperature Deviations in the Troposphere and Low Stratosphere, 1958–1999

*Angell, J. K., Air Resources Laboratory, National Oceanic and Atmospheric Administration, Silver Spring, Maryland  
Prepared by Dale Kaiser and Sonja Jones, CDIAC*

NDP-008 (updated 2000) (<http://cdiac.esd.ornl.gov/ndps/ndp008.html>)

Surface temperatures and thickness-derived temperatures from a global network of 63 radiosonde stations were used to estimate annual and seasonal temperature deviations (calculated relative to a 1958–1977 reference period mean) over the globe and several zonal regions from 1958 through 1999.

Most of the values are column-mean temperatures obtained from the differences in height between constant-pressure surfaces at individual radiosonde stations. The pressure-height data before 1980 were obtained from published

values in *Monthly Climatic Data for the World*. Between 1980 and 1990, Angell used data from both the *Climatic Data for the World* and the Global Telecommunications System (GTS) Network received at the National Meteorological Center. Between 1990 and 1995, the data were obtained only from GTS, and since 1995 the data have been obtained from National Center for Atmospheric Research files. These temperature deviations may be used to analyze long-term temperature trends for a layer of the atmosphere (i.e., surface, troposphere, tropopause, and low stratosphere), a region (i.e.,

polar, temperate, subtropical, and equatorial regions), a hemisphere, or the globe.

Additional information, including updated methods, trends, and graphics, is described in

CDIAC's *Trends Online*. For more details see page 8 or visit our Web site (<http://cdiac.esd.ornl.gov/trends/temp/angell/angell.html>). ☺

## Global, Regional, and National CO<sub>2</sub> Emission Estimates from Fossil Fuel Burning, Cement Production, and Gas Flaring: 1751–1997

Marland, G., T. A. Boden, CDIAC; and R. J. Andres, University of North Dakota

NDP-030 (revised 2000) (<http://cdiac.esd.ornl.gov/ndps/ndp030.html>)

Global, regional, and national annual estimates of CO<sub>2</sub> emissions from fossil fuel burning, cement production, and gas flaring have been calculated through 1997, some as far back as 1751. These estimates, derived primarily from energy statistics published by the United Nations (UN), were calculated through methods of Marland and Rotty (1984). Cement production estimates from the U.S. Department of Interiors Bureau of Mines were used to estimate CO<sub>2</sub> emitted during cement production.

Emissions from gas flaring were derived primarily from UN data but were supplemented with data from DOE's Energy Information Administration (Rotty 1974) and with some national estimates provided by Marland.

Additional information, including updated methods, trends, and graphics, is described in CDIAC's *Trends Online*. For more details see page 6 or visit Web site ([http://cdiac.esd.ornl.gov/trends/emis/em\\_cont.htm](http://cdiac.esd.ornl.gov/trends/emis/em_cont.htm)). ☺

## ALE/GAGE/AGAGE

Prinn, R., Massachusetts Institute of Technology; D. Cunnold, F. Alyea, D. Hartley, and R. H. J. Wang, Georgia Institute of Technology; P. Fraser and L. P. Steele, Commonwealth Scientific and Industrial Research Organisation; R. Weiss, Scripps Institution of Oceanography; P. Simmonds, International Science Consultants; Prepared by Tom Boden and Karen Gibson, CDIAC

DB1001 (updated 2000) (<http://cdiac.esd.ornl.gov/ndps/alegage.html>)

In the ALE/GAGE/AGAGE global network program, continuous high frequency gas chromatographic measurements of two biogenic/anthropogenic gases [methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O)] and six anthropogenic gases [chlorofluorocarbons (CFCl<sub>3</sub>, CF<sub>2</sub>Cl<sub>2</sub>, and CF<sub>2</sub>ClCFCl<sub>2</sub>); methyl chloroform (CH<sub>3</sub>CCl<sub>3</sub>); chloroform (CHCl<sub>3</sub>); and carbon tetrachloride (CCl<sub>4</sub>)] were collected at five globally distributed sites. Additional important species (H<sub>2</sub>, CO, HFC-134a, HCFC-141b, and HCFC-142b) have been added at select sites in recent years. The program, which began in 1978, is divided into

three parts associated with three changes in instrumentation: the Atmospheric Lifetime Experiment (ALE), which used Hewlett Packard HP5840 gas chromatographs; the Global Atmospheric Gases Experiment (GAGE), which used HP5880 gas chromatographs; and the present Advanced GAGE (AGAGE), which uses a new, fully automated system from the Scripps Institution of Oceanography (SIO) containing a custom-designed sample module and HP5890 and Carle Instruments gas chromatographic components. The current station locations are Cape Grim, Tasmania; Cape Matatula,

American Samoa; Ragged Point, Barbados; Mace Head, Ireland; and Trinidad Head, California. Stations had previously existed at Cape Meares, Oregon, and Adrigole, Ireland. The current Mace Head station replaced the Adrigole station and the station at Trinidad Head replaced the Cape Meares station.

Presently, data from all three experiments are available. Data through August or September 1999 are now available for all five existing sites. Individual measurements (generally made four times daily at each site for ALE, 12 times daily

at each site for GAGE, and more than 30 times daily at each site for AGAGE) and monthly summary averages are provided for each site. All ALE and GAGE data have been recalculated according to the current AGAGE calibration standards, thus creating a unified ALE/GAGE/AGAGE data set based upon the same standards. All ALE/GAGE/AGAGE data presented here are reported in the SIO-1998 calibration scale (Prinn et al. 2000. A history of chemically and radiatively important gases in air deduced from ALE/GAGE/AGAGE. *Journal of Geophysical Research*, 105:17751-92.). ☺

## Bibliography on CO<sub>2</sub> Effects on Vegetation and Ecosystems: 1990–1999 Literature

*Jones, Michael H., and Peter S. Curtis, The Ohio State University  
Prepared by Robert M. Cushman, CDIAC*



ORNL/CDIAC-129 (2000) (<http://cdiac.esd.ornl.gov/epubs/cdiac/cdiac129/cdiac129.html>)

This database provides complete bibliographic citations (plus abstracts and keywords, when available) for more than 2700 references published between 1990 and 1999 on the direct effects that elevated atmospheric concentrations of CO<sub>2</sub> have on vegetation, ecosystems, their components, and interactions. This database is also an update to *Direct Effects of Atmospheric CO<sub>2</sub> Enrichment on Plants and Ecosystems: An Updated Bibliographic Data Base* (ORNL/CDIAC-70), edited by Boyd R. Strain and Jennifer D. Cure. That database covered literature from 1980 to 1994. This bibliography

was developed to support The Ohio State University's (OSU's) Carbon Dioxide Meta-Analysis Project (CO<sub>2</sub>MAP) but was designed to be useful for a wide variety of purposes related to the effects of elevated CO<sub>2</sub> on vegetation and ecosystems.

The database is available as a Papyrus bibliographic database. In addition, an alphabetical (by author) listing of the bibliography is available in WordPerfect, ASCII, and pdf formats. A keyword index may be used to locate specific citations of interest. ☺

## Graduate Student Theses Supported by DOE's Environmental Sciences Division: Fiscal Year 2000 Update

*Cushman, Robert, CDIAC; Alisa Harrison and Katie Stevens, National Institute for Global Environmental Change National Office, University of California, Davis*

ORNL/CDIAC-130 (2000) (<http://cdiac.esd.ornl.gov/epubs/cdiac/cdiac130/cdiac130.htm>)

*The Graduate Student Theses Supported by  
DOE's Environmental Sciences Division: Fiscal*

*Year 2000 Update* is an addendum to the 1995 report *Graduate Student Theses Supported by*

*DOE's Environmental Sciences Division.* The update provides complete bibliographic citations, abstracts, and keywords for 70 doctoral and masters' theses published between 1994 and 2000 that were supported fully or partly by DOE's Environmental Sciences Division in the following areas: Atmospheric Chemistry; Marine Transport; Carbon, Climate,

and Vegetation; Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP); Coastal Margins; and National Institute for Global Environmental Change (NIGEC). Information on the major professor, department, principal investigator, and program area is given for each abstract. ☺

## Reference Links



American Geophysical Union (AGU)  
Geophysical Research Letters (GRL) -  
<http://www.agu.org/GRL/>

American Meteorological Society (AMS) -  
<http://www.ametsoc.org/AMS/>

Atmospheric Radiation Measurement (ARM)  
Archive - <http://www.archive.arm.gov/>

Brookhaven National Laboratory (BNL) FACE  
Group - <http://www.face.bnl.gov/>

Carbon Dioxide Information Analysis Center  
(CDIAC) - <http://cdiac.esd.ornl.gov/>

China Meteorological Administration (CMA) -  
<http://www.cma.gov.cn/>

Climate Change Prediction Program - (formerly  
CHAMMP—Computer Hardware, Advanced  
Mathematics, and Model Physics) -  
<http://www.epm.ornl.gov/chammp/chammp.html>

Climatic Research Unit (CRU), University of  
East Anglia - <http://www.cru.uea.ac.uk/>

Documents of the Conference of the Parties, at its  
Third Session, (COP 3) -  
<http://www.unfccc.de/resource/cop3.html>

DOE Energy Information Administration (EIA) -  
<http://www.eia.doe.gov/>

DOE Environmental Sciences Division (ESD) -  
[http://www.er.doe.gov/production/ohr/  
ESD\\_top.html](http://www.er.doe.gov/production/ohr/ESD_top.html)

DOE Global Change Education Program  
(GCEP) - <http://www.atmos.anl.gov/GCEP/>

DOE Office of Biological and Environmental  
Research (OBER) - [http://www.er.doe.gov/  
production/ober/ober\\_top.html](http://www.er.doe.gov/production/ober/ober_top.html)

DOE Office of Fossil Energy -  
<http://www.fe.doe.gov/>

DOE Office of Science - <http://www.er.doe.gov/>

DOE Office of Science: Carbon Sequestration -  
<http://cdiac2.esd.ornl.gov/>

FACE 2000 Conference -  
[http://ws234.niaes.affrc.go.jp/riceface/News/  
announcement.htm](http://ws234.niaes.affrc.go.jp/riceface/News/announcement.htm)

FLUXNET - [http://www.daac.ornl.gov/  
FLUXNET/index.html](http://www.daac.ornl.gov/FLUXNET/index.html)

Georgia Institute of Technology -  
<http://www.gatech.edu/>

Global Change Data and Information System  
(GCDIS) - <http://globalchange.gov/>

The Global Telecommunication System (GTS),  
World Meteorological Organization -  
[http://www.wmo.ch/web/www/TEM/ gts.html](http://www.wmo.ch/web/www/TEM/gts.html)

Intergovernmental Panel on Climate Change (IPCC) - <http://www.ipcc.ch/>

Massachusetts Institute of Technology (MIT) - <http://www.mit.edu/>

Mauna Loa Observatory (MLO) - <http://stratus.mlo.hawaii.gov/>

National Center for Atmospheric Research (NCAR) - <http://www.ncar.ucar.edu/ncar/>

National Institute for Global Environmental Change (NIGEC) - <http://nigec.ucdavis.edu/>

National Technical Information Service (NTIS) - <http://www.ntis.gov/>

National Oceanic and Atmospheric Administration (NOAA) - <http://www.noaa.gov/>

NOAA Air Resources Laboratory (ARL) - <http://www.arl.noaa.gov/>

NOAA Pacific Marine Environmental Laboratory (PMEL) - <http://www.pmel.noaa.gov/>

North Pacific Marine Science Organization (PICES) - <http://pices.ios.bc.ca/>

Oak Ridge National Laboratory (ORNL) - <http://www.ornl.gov/>

Office of Scientific and Technical Information (OSTI) - <http://www.osti.gov/>

The Ohio State University (OSU) - <http://www.osu.edu/>

ORNL Distributed Active Archive Center (DAAC) - <http://www.daac.ornl.gov/>

ORNL Energy Division - <http://www.ornl.gov/divisions/energy/energy.html>

ORNL Environmental Sciences Division (ESD) - <http://www.esd.ornl.gov/>

Rosenstiel School of Marine and Atmospheric Science - <http://www.rsmas.miami.edu/>

Scripps Institution of Oceanography (SIO) - <http://www.sio.ucsd.edu/>

U.K. Met (Meteorological) Office - <http://www.metoffice.gov.uk/>

United Nations (UN) - <http://www.un.org/>

University of Montana Numerical Terradynamic Simulation Group (NTSG) - <http://www.forestry.umont.edu/ntsg/>

University of North Dakota - <http://www.und.nodak.edu/>

University of Washington Department of Atmospheric Sciences - <http://www.atmos.washington.edu/>

U.S. Department of Energy (DOE) - <http://energy.gov/>

U.S. Global Change Research Information Office (GCRI) - <http://www.gcrio.org/>

U.S. Global Change Research Program (USGCRP) - <http://www.usgcrp.gov/>

U.S. Government Printing Office (GPO) - <http://www.gpo.gov/>

U.S. Office of Technology Assessment (OTA) - <http://www.ota.nap.edu/index.html>

UT-Battelle, LLC - <http://www.ut-battelle.org/>

WOCE (World Ocean Circulation Experiment) Hydrographic Program Office - <http://whpo.ucsd.edu/> ☺

**NOTE!!**

Internet sites listed in *CDIAC Communications* are Web sites that were available at the time of publication. Internet users should realize that Web sites are subject to change without notice.

## CDIAC's Bookshelf



*In the course of our work at CDIAC, many books and announcements cross our desks. Many of these are highly specialized and may not get a broad announcement to the worldwide scientific community, so we'd like to share them in this feature of CDIAC Communications. CDIAC does **not** stock or distribute these publications.*

### **National Assessment Synthesis Team, Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change** (<http://www.gcrio.org/NationalAssessment/>)

The National Assessment Synthesis Team (NAST) recently wrote and released an Assessment Overview based on a longer, referenced "Foundation" report (which is running about a month behind publication of the Overview). This Assessment was written as part of a major ongoing effort to understand what climate change means for the United States. This Assessment has begun a national process of research, analysis, and dialogue about the coming changes in climate, their impacts, and what Americans can do to adapt to an uncertain and continuously changing climate.

Copies of the Overview are available from Cambridge University Press, 110 Midland Avenue, Port Chester, NY 10573 for US \$16.95. Sections of the report may be downloaded from the Web (<http://www.gcrio.org/NationalAssessment/>). Copies of the Foundation report (expected to be about 800 pages long) will also be available from Cambridge University Press at an estimated price of \$40.00. Copies of the chapters of the report will also be available on the Web. ☺



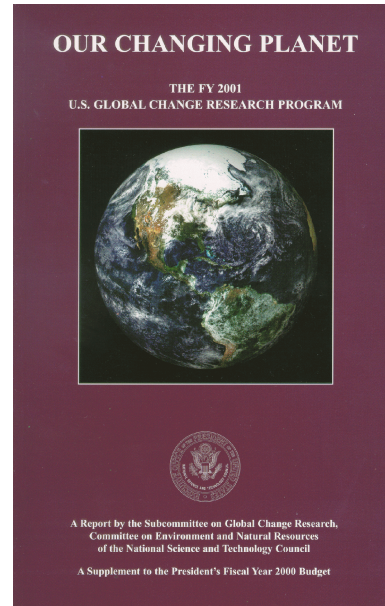
### **Our Changing Planet: The Fiscal Year 2001 U.S. Global Change Research Program** (<http://gcrio.ciesin.org/ocp2001/>)

Our Changing Planet: The FY 2001 Global Change Research Program is a report to Congress supplementing the President's FY 2001 budget, pursuant to the Global Change Research Act of 1990. The report describes the U.S. Global Change Research Program (USGCRP); summarizes recent highlights in global change research, assessment, and observations, and highlights of the FY 2001 budget; discusses the seven Program Elements and FY 2001 plans in each of these research

May 2001

areas; and includes an appendix that details the FY 2001 budget, including program components and program highlights for each of the departments and agencies that comprise the USGCRP. Achieving the goals of this program will require continued strong support for the scientific research needed to improve understanding of how human activities are affecting the global environment, and of how natural and human-induced global change is affecting society and ecosystems.

A printed copy of this publication can be obtained without charge by mail from GCRIO User Services, P.O. Box 1000, 61 Route 9W, Palisades, New York 10964 (USA); by e-mail from [help@gcrio.org](mailto:help@gcrio.org). It may also be downloaded via the Internet (<http://gcrio.ciesin.org/ocp2001/>). ☺



## Have You Visited Lately?

### Global Change Data and Information System



<http://www.globalchange.gov/>

### U.S. Global Change Research Program



<http://www.usgcrp.gov/>

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**Carbon Dioxide Information Analysis Center  
World Data Center for Atmospheric Trace Gases**



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